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SYNOPSIS

ON

Diffraction Analysis in Metamaterial-Loaded Antennas using a Modified GTD Approach

BY

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For

PhD Degree in Physics (Faculty of Science)

Under the Supervision

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SYNOPSIS FOR Ph. D. DEGREE IN PHYSICS

FACULTY OF SCIENCE

1. TITLE OF THE RESEARCHSYNOPSIS:

Diffraction Analysis in Metamaterial-Loaded Antennas using a Modified GTD Approach

2. WORK - PLAN:

a. Purpose and Need of the Study:

This research investigates how metamaterial loading of antennas modifies edge and aperture diffraction and develops a modified Geometrical Theory of Diffraction framework to accurately predict the resulting scattering, radiation patterns and near-field behavior. The study aims to produce a semi-analytical diffraction model that captures metamaterial-induced anomalous local fields .It extends GTD/UTD diffraction coefficients to account for engineered effective parameters. It also validates the modified GTD against full-wave numerical simulation and measurements for representative metamaterial-loaded antenna geometries. Metamaterials and metasurfaces have become a mainstream tool in antenna engineering because they can improve gain, control radiation patterns, reduce surface waves, and miniaturize elementsby tailoring near-field and boundary interactions. However, many classical analytical and ray-based methods assume canonical homogeneous media and PEC/standard dielectric boundaries; they do not account for the complex boundary conditions and surface/evanescent phenomena introduced by metamaterial layers or unit-cell resonances. Designers

therefore rely heavily on computationally expensive full-wave solvers (FEM, FDTD, MoM) for every geometry and frequency of interest, which is time-consuming for parametric studies and system-level ray-tracing applications. A modified GTD that incorporates metamaterial effective parameters would enable fast, physics-based insight and efficient prediction of scattering/diffraction from edges and apertures in metamaterial-loaded antennas—bridging the gap between rigorous numerics and intuitive ray-based design. It is of great importance to study how metamaterial superstrates, substrate inclusions and metasurfaces modify canonical edge/aperture diffraction mechanisms.It also needed to know how GTD diffraction coefficients be generalized systematically using homogenized effective parameters and surface impedance models for common metamaterial unit cells.

We will also study the accuracy domain (frequency, unit-cell size, distance from edges) of the proposed modified GTD compared with full-wave methods and measurements.

(b) Details of the Project with Chapterization

This research project would be made to develop theory, perform numerical validation, fabricate prototype antenna structures, and measure/compare results. The work will be split into six main chapters.

Chapter 1. In this part of the thesis we will present the Introduction, Context, Objectives and Scope of this study. We will study about metamaterial vs metasurface, homogenization limits, GTD/UTD basics, edge diffraction, surface impedance models. We will also make methodology overview, expected contributions, and chapter map.

Chapter 2. In this part of the thesis we will present the Literature Review and State of the Art. The metamaterial loading techniques for antennas will also be presented here. Review of canonical diffraction theory:

Keller's GTD, UTD, uniform asymptotic techniques, and modern revisions will also be presented here.

Chapter 3. In this part of the thesis Theoretical Development regarding Modified GTD for Metamaterial Boundaries Statement of assumptions and homogenization validity will be presented. The derivation roadmap of canonical GTD including incident ray, reflected ray, diffracted ray from edge sources would be described.

Chapter 4. In this part of the thesis Numerical Implementation and Simulation studies will be presented. The Validation plan with canonical cases such as dielectric wedge, impedance wedge, benchmark against classical GTD/UTD results and available analytic solutions will also be made.

Chapter 5. In this part of thesis Design and fabrication details of representative prototypes such as microstrip patch + metamaterial superstrate printed on Rogers/FR4, metasurface ground sample would be studied.

Chapter 6. In this part of the thesis Results, Discussion and Conclusions will be presented. The future work extensions to large arrays, time-domain GTD, nonlocal homogenization, machine-learning assisted coefficient calibration will also be described here.

c. Methodology

The research methodology integrates theoretical derivation, numerical simulation, prototype fabrication and measurement. It is described here step-by-step.

In the first step Problem formalization & homogenization strategy will be made. We will identify metamaterial configurations such as superstrate, substrate inclusions and metasurface ground. We will also determine

whether homogenization such as bulk effective $\varepsilon(\omega)$, $\mu(\omega)$, anisotropy is appropriate or whether a surface-impedance/metasurface model better represents the unit-cell physics (resonant, electrically thin structures). For electrically small unit cells use standard S-parameter retrieval or effective-parameter extraction; for thin metasurfaces, extract a surface impedance/admittance dyadic.

In the second step theoretical derivation will be made which is Modified GTD.

We will start from canonical GTD formulation in which incident, reflected and diffracted ray fields would be expressed with diffraction coefficients dependent on wedge parameters and polarization. We will replace perfect conductor/dielectric boundary conditions with generalized impedance/dyadic boundary conditions that represent the metamaterial effective response.

In the third step we will consider the evanescent contributions.Many metamaterials support surface waves or strong evanescent fields near the structure. We will incorporate these by adding explicit surface-guided wave terms in the total field representation, coupling to the diffracted field via coupling coefficients derived from boundary-matching. This is critical to predict pattern ripple and near-edge field enhancement typical of resonant metamaterials.

d. REFERENCES:

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I testify that I am in a position to devote time for this research work and undertake to complete this research work within specified maximum time limit.

Full signature of the research scholar

with date.

The candidate has undertaken to complete the research work under my supervision and guidance under the time limit.

Full signature of the supervisor

with date designation and address .